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Using ASME Section VIII Division 2 Class 1 to your advantage

It is globally recognized that ASME codes are widely used international codes for the construction of mechanical equipment operating in power, refining, petrochemical and nuclear facilities. These codes, along with other ASME standards, address every aspect of their construction, such as component selection, ratings, materials, design, fabrication, welding, examination, inspection, testing and certification. These codes are continually updated according to the needs of the industry.

ASME codes are published in 12 sections. Section VIII is for the construction of pressure vessels. *Pressure vessel* is a generic reference that includes simple vessels, drums, tall columns, thick-walled vessels and reactors. Section VIII is further divided into divisions—Divisions 1 and 2 are the most widely used.

As a practice, Division 1 is selected for pressure vessels with design conditions resulting in low-to-moderate wall thickness (i.e., up to 50 mm). Division 2 is used for cases requiring higher thickness, although there are other factors—such as high pressure, cyclic service, service fluid, complexity of design, and client specifications—that can mandate a Division 2 designation. Division 2 provides detailed design procedures (both formula-based and analytical) and higher permissible stresses for the commonly used carbon and low-alloy steel materials, of which most pressure vessels are fabricated. Therefore, vessels requiring a higher wall thickness often benefit from adhering to Division 2 due to the reduced required wall thickness, which reduces the vessel's weight. Other indirect benefits of lighter vessels are ease of handling at fabrication shops, less welding, less transportation and erection efforts, and a lighter foundation.

However, the advantages are not always obvious. Complying with additional requirements put forth by Division 2 on quality systems, materials, inspections, testing and documentation involving designers and certifying engineers have a potential to offset the benefits it might offer otherwise. Therefore, it is imperative to carry out a detailed cost assessment involving direct and indirect savings vs. expenses for complying with additional requirements. In the past, Division 1 was the only code of choice when the outcome of the above assessment fell toward the right of the breakeven point.

In the 2017 edition, Division 2 had an important addition in it—the introduction of two vessel classes: Class 1 and Class 2. Class 1 vessels are important, as they provide an intermediate solution to the situations described previously. Class 2 vessels are vessels that are built in full compliance to Division 2 as done prior to the 2017 edition.

ASME Section VIII Division 2: Class 1 vessels. Class 1 pressure vessels are still required to comply with all the rules and requirements of Division 2. However, there are a few limitations and exemptions, which include the following:

- Class 1 vessels are limited only to design-by-rule methods. Design-by-analysis methods are permitted only for those components for which design rules are not available. Design-by-analysis methods cannot be used in lieu of design-by-rule methods.
- Class 1 vessels still require a user's design specification (UDS), but it is exempted from endorsement by a certifying engineer unless the vessel is in cyclic service

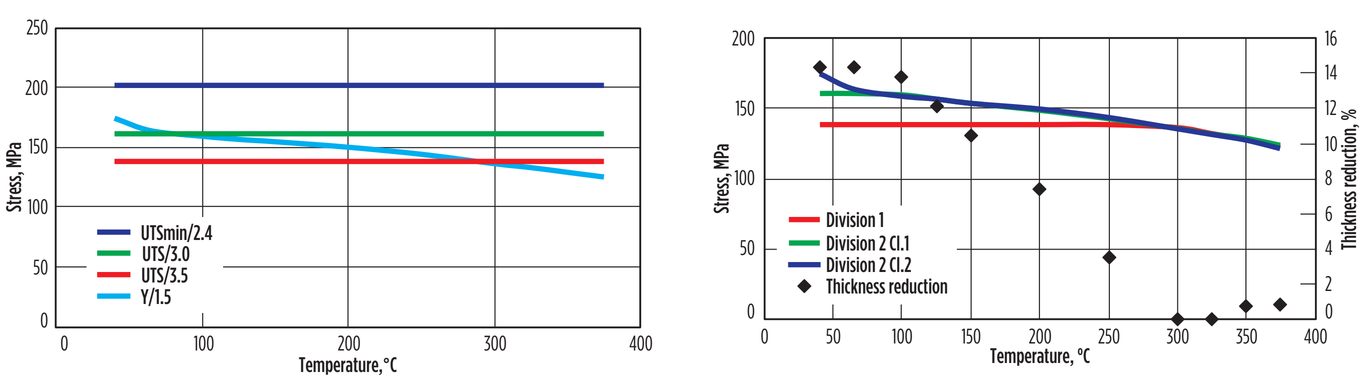

FIG. 1. Plot for SA-516 Gr.70 (carbon steel). (A) *y(T), UTS(T)* and UTS_{min} with design margins; (B) allowable stresses and percent reduction in wall thickness between Division 1 and Division 2 Class 1.

requiring detailed fatigue analysis (cycles > 1,000).
- Class 1 vessels still require a vessel manufacturer to develop a manufacturer's design report, but it is exempted from endorsement by a certifying engineer unless a detailed fatigue analysis is required by the UDS and/or design-by-analysis methods are employed.

It is now simpler for fabrication shops that are already authorized to manufacture Division 1 vessels to obtain authorization to manufacture Class 1 vessels without a need to undergo full assessments amounting to Division 2. This reduces the dependency on only a few fabrication shops that are authorized to manufacture Division 2 vessels. The requirements on materials, fabrication, inspection, testing and marking are the same for both classes, with minimal changes. Therefore, Class 1 vessels can be treated as vessels that are built to Division 2 quality, and these vessels can be economical vs. Division 1.

Division 2 rules result in lesser wall thickness vs. Division 1 due to the different theories of failures that they are based on. With the introduction of Mandatory Appendix 46 in Division 1 (or due to the presence of Code Case 2695), it has now become on par with Division 2 in terms of design rules. Therefore, with everything else becoming the same, the distinguish-

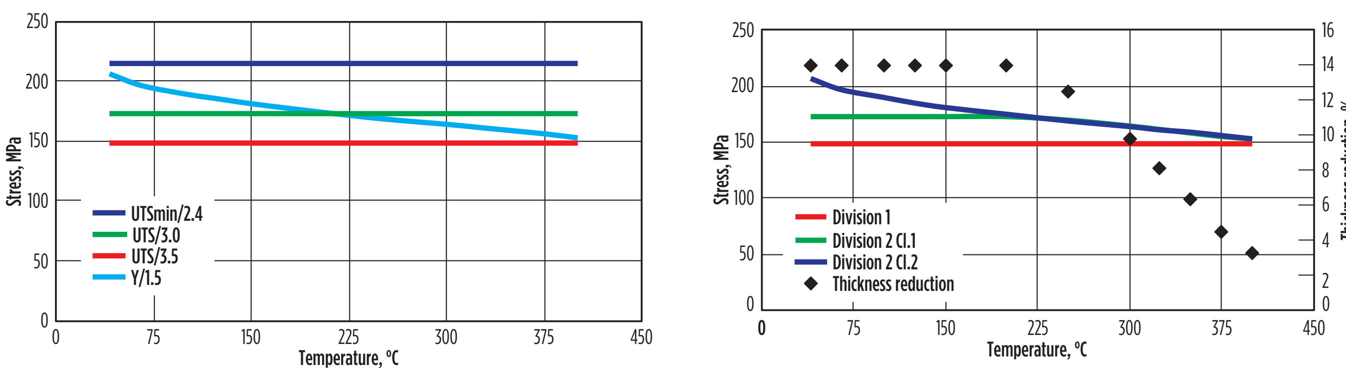

FIG. 2. Plot for SA-387 Gr.11 Cl.2 (1.25 Cr-0.5 Mo): (A) *y(T), UTS(T)* and UTS_{min} with design margins; (B) allowable stresses and percent reduction in wall thickness between Division 1 and Division 2 Class 1.

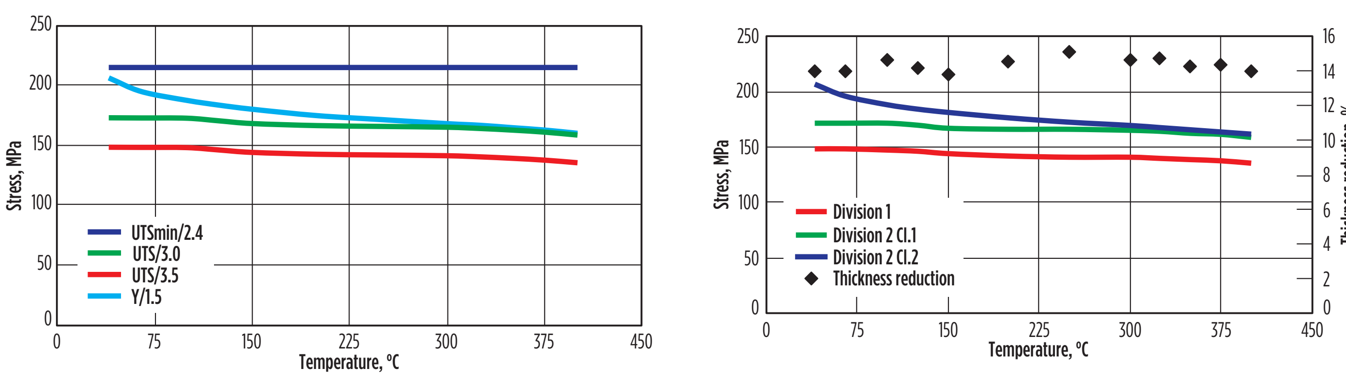

FIG. 3. Plot for SA-387 Gr.22 Cl.2 (2.25 Cr-1 Mo): (A) *y(T), UTS(T)* and UTS_{min} with design margins; (B) allowable stresses and percent reduction in wall thickness between Division 1 and Division 2 Class 1.

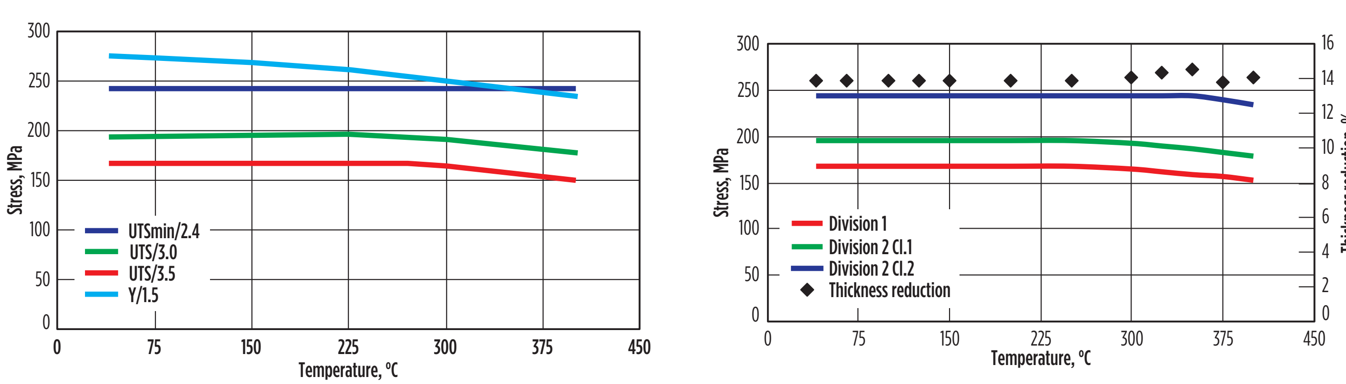

FIG. 4. Plot for SA-542 Ty.D Cl.4a (Cr-Mo-V): (A) *y(T), UTS(T)* and UTS_{min} with design margins; (B) allowable stresses and percent reduction in wall thickness between Division 1 and Division 2 Class 1.

ing feature between Division 1, Division 2 Class 1, and Division 2 Class 2 is their values of maximum permissible stresses.

The availability of more shops to fabricate Class 1 vessels means the availability of more suppliers locally and internationally, with the possibility of obtaining more competitive pricing.

Maximum permissible stress is defined as the maximum unit stress permitted in materials used in the construction of pressure vessels, and this can be expressed in its most simplified form (Eq. 1):

$$S = min\left\{\frac{y(T)}{1.5}, \frac{UTS(T)}{DM}\right\} \quad (1)$$

where:
$y(T)$ = Yield strength of materials at temperature (T)
$UTS(T)$ = Tensile strength of materials at temperature (T).
Note: $UTS(T) = UTS_{min}$ for Division 2 Class 2 where UTS_{min} is the minimum specified tensile strength, which is a constant value.
DM = The design margin (3.5 for Division 1, 3 for Division 2 Class 1, and 2.4 for Division 2 Class 2).

It is interesting to note that the design margin used to be 3 for Division 2 prior to the 2007 edition of the standard, when it was improved to 2.4. However, in the 2017 edition, it was split into 2.4 and 3 to accommodate the two vessel classes.

Assuming $y(T)/1.5$ is not governing either for the material or at a temperature T, then it is the value of the design margin on tensile strength that governs the allowable stress for that material at that temperature.

To understand how these design margins impact the allowable stresses that impact the required wall thickness, the plots of $y(T)$, $UTS(T)$, UTS_{min} and allowable stresses, percent reduction in wall thickness between Class 1 and Division 1 for commonly used carbon steel, chromium molybdenum (Cr-Mo) and chromium molybdenum vanadium (Cr-Mo-V) pressure vessel plate materials are provided in **FIGS. 1–4.** The plate material is selected for the plots, as they contribute to the bulk of the vessel weight as fabricated. As the thickness is proportional to vessel diameter and internal pressure, the plotted reduction in thickness holds true for a range of vessel dimensions and internal pressures.

From the plots in **FIGS. 1–4,** it is evident that the allowable stresses of Class 1 are higher than Division 1 over a reasonable temperature range or until the yield starts governing. With everything else the same, it is these higher allowable stresses that result in reduced wall thickness. As seen in the plots, a 5%–15% reduction in wall thickness could be expected in Class 1 vessels vs. Division 1. However, it may still be beneficial to design critical equipment (e.g., hydroprocessing reactors) to Division 2 Class 2, as they are normally built to higher grades of low-alloy steels and their allowable stresses are highest among the three categories.

Takeaway. With the introduction of the Class 1 vessel category in Division 2, ASME Section VIII now provides an additional option to the vessel engineer to design vessels. In the past, vessels had to be designed to either Division 1 or Division 2, which is now Class 2.

If properly evaluated, Class 1 vessels could provide an overall advantage vs. Division 1, especially to an engineering, procurement and construction (EPC) contractor. Class 1 vessels have higher allowable stresses, which mean reduced wall thickness—and, hence, lighter vessels. Lighter vessels tend to be less capital-intensive, and require lighter foundation or structure, along with less transportation and erection costs. Furthermore, in some cases, the exemption of a UDS certification means that a vessel engineer requires less effort to issue a UDS. Lastly, the availability of more shops to fabricate Class 1 vessels means availability of more suppliers locally and internationally, with the possibility of obtaining more competitive pricing.

It now makes sense for EPC contractors to perform a preliminary investigation during the design phase of a project (i.e., front-end engineering design) about the potential benefits of Class 1, and to define their purchase specifications accordingly. Alternatively, vessel suppliers could perform similar activities and make suitable proposals to the purchasers, as well. HP

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